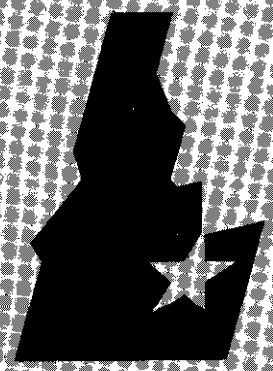

Idaho National Engineering Laboratory

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INFORMAL REPORT

INTERIM-ACTION RISK ASSESSMENT FOR THE TEST REACTOR AREA (TRA) WARM-WASTE LEACH POND SEDIMENTS (OU-2-10)

I. del C. Figueroa
Y. McClellan
J. J. King

EG&G Idaho

Work performed under DOE Contract No. DE-AC07-76ID01570

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EG&G Idaho, Inc.
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INTERIM-ACTION RISK ASSESSMENT FOR THE TEST REACTOR AREA (TRA) WARM-WASTE LEACH POND SEDIMENTS (OU-2-10)

APPROVED BY:

Lois C Van Deusen — 5/29/91
WAG-2 Unit Manager — Date

REVIEWED BY:

John B. Pelroshi for R.L. Nitschke — 5/29/91
Chemical & Radiological Risk Assessment Unit Manager — Date

DALE CLAFLIN BY — 5/29/91
Publications Processing — Date

ABSTRACT

This report provides an interim-action risk assessment for the TRA Warm Waste Leach Pond Sediments in support of the designated response action of the Interagency Agreement (IAG) Action Plan (Rev. 7). The potential risks associated with the pond sediments and liquid waste were determined based on the present condition of the operable unit under institutional control. The risk assessment effort included a human health evaluation and an ecological assessment of the operable unit.

Liquid and sediment samples acquired from the pond during 1988 provided the basis for establishing concentrations of chemicals and radionuclides, which were then used in the risk assessment. The potential exposure pathways and toxic effects to both human and ecological receptors were evaluated.

The human health evaluation involved the determination of noncarcinogenic and carcinogenic risks for a hypothetical receptor located at the boundary of the operable unit. Because the site is under institutional control, the exposure scenario was defined as a current occupational scenario. Two exposure pathways were examined: inhalation of soil-contaminated air and external exposure (for radionuclides only). Risk results for the noncarcinogenic and carcinogenic effects of site-related chemicals were below the level of concern for the evaluated exposure pathway (inhalation). Carcinogenic risk for inhalation of radionuclides was also below, or within, the accepted National Contingency Plan (NCP) target risk range of 10-4 to 10-6. The external exposure cancer risk, for all the analyzed exposure conditions, was found to exceed the NCP risk range. The major contributors to the calculated cancer risk for the external exposure hazard were Co-60 and Cs-137.

The ecological assessment examined the acute and chronic effects on flora and fauna exposed to chemicals and radionuclides at the TRA-Warm Waste Pond. Actual and potential exposure pathways were identified. The ecological exposure assessment evaluated two exposure pathways: ingestion of water and ingestion of contaminated soil. Evidence suggests that chemicals present at

the TRA-Warm Waste Pond could be toxic to certain species of plants and wildlife. The evaluation for radionuclides was limited by the lack of toxicity standards to compare to onsite values. In absence of such EPA standards, the radionuclides concentrations were compared to a limit suggested by the International Atomic Energy Agency.

A separate risk assessment calculation was performed to evaluate the ingestion of soil for a future residential scenario. The results of this evaluation are shown in Appendix I-C.

CONTENTS

FIGURES

TABLES

INTERIM ACTION RISK ASSESSMENT FOR THE TEST REACTOR AREA (TRA) WARM WASTE LEACH POND SEDIMENTS (OU-2-10)

I. HUMAN HEALTH RISK ASSESSMENT

1. INTRODUCTION

The purpose of this report is to provide an interim-action risk assessment for the sediments associated with the Test Reactor Area (TRA) warm waste leach pond (WWP) at the Idaho National Engineering Laboratory (INEL). The warm waste leach pond consists of three cells (52, 57, and 64) which receive, or have received, liquid waste generated at TRA. At the present time, one-third of the surface area of, cell 52 is covered with liquid, cell 57 is totally covered with liquid, and cell 64 is completely dry. The cell conditions noted above will be assumed for this risk assessment. Liquid and sediment samples acquired during 1988 provided the basis for establishing concentrations of radionuclides and chemicals that are present.

The human health portion of this risk assessment involved the determination of potential exposures and risks associated with the identified site-related contaminants. Because the operable unit is under actual institutional control, the potential exposure scenario at the TRA-WWP was defined as an occupational scenario. The hypothetical receptor was assumed to be located at the boundary of the operable unit and estimates of exposure were used in the risk determination. Two exposure pathways were analyzed: inhalation of soil-contaminated air and external exposure (for radionuclides only). Different exposure conditions were examined to include upper-bound cases, average cases, and more realistic exposures. A toxicity assessment was conducted to determine the health effects associated with the identified contaminants. Noncarcinogenic and carcinogenic toxicity values were identified or derived to perform the risk assessment. Risks were quantified for the selected contaminants of concern (individually), for multiple substances, and for multiple pathways (for radionuclides). Noncarcinogenic

effects were evaluated based on the hazard quotient/index of toxicity, relative to unity. Carcinogenic risks were evaluated and compared to the accepted NCP target risk range of 10-4 to 10-6.

2. LIQUID AND SEDIMENT CONTAMINANT CONCENTRATIONS

Reports written by Hull[1] and Frazier et al.[2] were examined for pertinent information. The desired information involved data from the 1988 remedial response investigation for the WWP. Radionuclide media concentrations were taken from Anderson[3]; the chemical concentrations were acquired from Rehak[4]. Reference 3 provided validation of radiological data for 26 sediment samples and 4 water samples taken in and around the WWPs during 1988. Reference 4 tabulated analysis results for organic and inorganic substances that were detected at the WWP. At the time of writing of Reference 4, the entire process of chemical validation of the organic and inorganic data was still pending completion.

The WWP consists of three cells (52, 57, and 64). Figure I-1 displays the sampling locations in each cell for sediments that were acquired at 2-foot intervals down to a depth of 10 feet, during the 1988 remedial response investigation study. In addition, water samples were drawn at cells 52 and 57 and were analyzed for radionuclides. The analysis of the sampling data for this interim-action risk assessment was divided into two parts--the sediment and water samples.

A potential hazard from the dry areas of cells 52 and 64 involves the movement of wind-driven contaminated dust to the areas outside the WWP. Hence, the sampled areas that are not covered by water should be represented by surficial (0-2 feet) sediment concentrations from the dry sediments. Additionally, the exposed (dry) cell-bottom-surface areas should be used to weight the surficial contaminant concentrations in order to create a realistic averaging of potential airborne contaminants. In order to accomplish this, sample concentrations at points O, P, Q, and R in cell 52 were directly averaged to compute an unweighted mean. The same was done for sample locations B, F, G, H, I, and J in cell 64. It was assumed that cell 52 was two-thirds dry and that cell 64 was completely dry. The areas exposed for cell 52 and cell 64 were computed by using bottom dimensions of 46 m x 76 m for cell 52

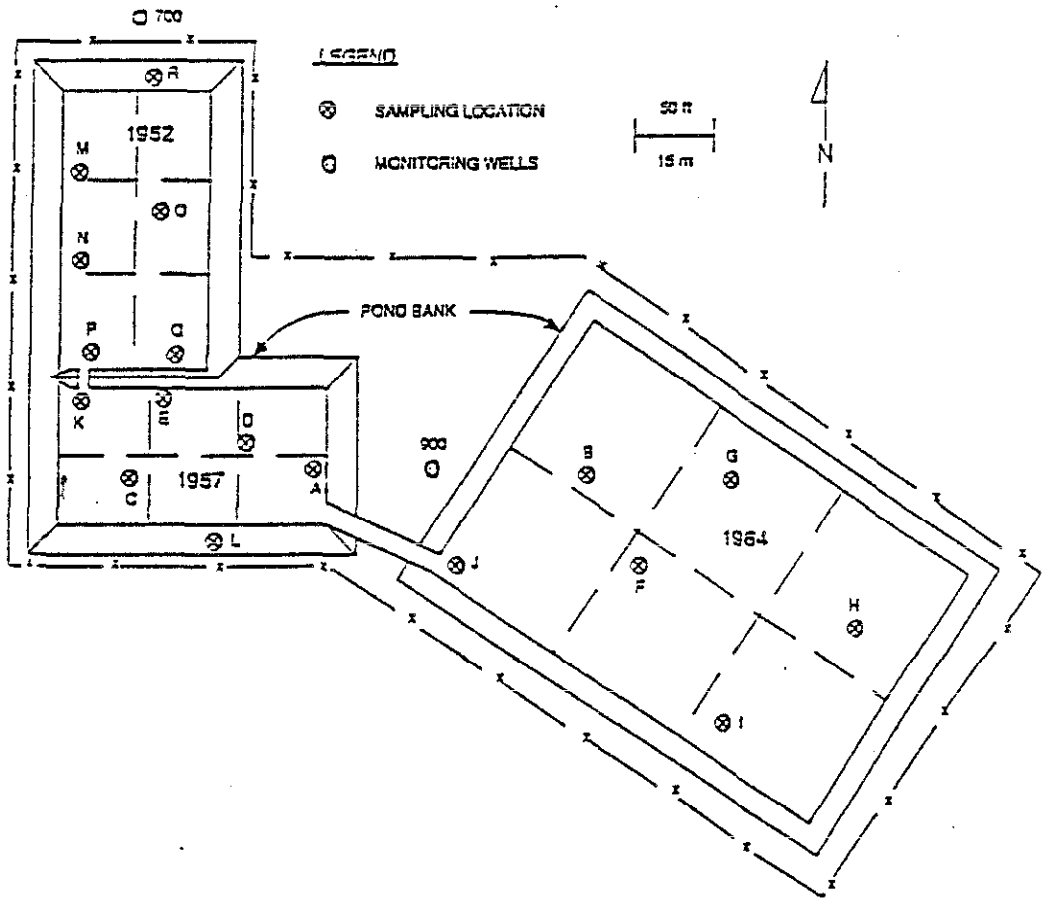

Figure I-1. Sediment sampling locations and monitoring well locations for the Phase I remedial response investigation at the TRA WWP.

and 76 m x 122 m for cell 64, as given in Reference 2. Assuming that two-thirds of the bottom of cell 52 is exposed, and summing this with the area of cell 64, surface area weighting factors of 0.201 and 0.799 were computed for mean contaminant concentrations for cell 52 and cell 64, respectively. The surface-weighted mean concentration was then computed for cells 52 and 64. This process was done for evaluated sediment concentrations of radionuclides and chemical substances for sediment samples acquired at depths of 0-2 feet. An exception to this algorithm occurred for beryllium. The average value for cell 52 was 2.2 ppm, but defaulted to 0 ppm for cell 64. The weighted average of these two values was 0.4 ppm. However, this is below the background limit of 1.1 ppm. Hence, the weighted average for beryllium was fixed at 2.2 ppm.

The qualifiers that were chosen for evaluation of measurements in References 3 and 4 must be noted. All qualified data (Q) and trend (T) data from Reference 3 were incorporated for computing weighted-mean radionuclide sediment concentrations. All the data accepted from Reference 4 had no qualifiers attached, except for one case in which a datum with an S qualifier (indicates value determined by Method of Standard Addition) was utilized.

For both radionuclide and chemical measurements, contaminant backgrounds from areas external to the TRA-WWP were not evaluated or subtracted for this study. K-40 was deleted from the radionuclide list since it was measured at naturally occurring levels found in the basalts of the eastern Snake River Plain. The contaminants, showing consistent "true positive" measured values at a depth of 0-2 feet, were selected for this study and are shown in Table I-1. Water samples displaying statistically "true positive" radionuclide concentrations are shown in Table I-2. No water samples were analyzed for chemicals for this study.

Table I-1 displays exposed-area-weighted average sediment concentrations for 19 radionuclides and 11 chemicals. The radionuclide concentrations are shown in picocuries per gram (pCi/g) and in milligrams per kilogram (mg/kg). The chemical concentrations are listed in parts per million (ppm), which is equivalent to milligrams per kilogram (mg/kg).

Table I-2 displays maximum water concentrations of 23 radionuclides for water samples taken from cells 52 and 57. Many of these detected radionuclides are relatively short-lived, and their presence represents constant replenishment by facilities at TRA. The majority of these maximum values are from cell 52, which tends to preferentially retain short-lived nuclides before they can reach mixing equilibrium with cell 57. For this risk assessment, it will be assumed that the maximum measured concentrations represent a steady-state environment to which human and ecological receptors may be exposed.

3. MASS-LOADING AIRBORNE CONCENTRATIONS

The righthand column of Table I-1 displays the mass-loading airborne concentrations for the sediment radionuclide concentration and sediment chemical concentrations. These numbers were derived by initially assuming that the weighted-average sediment concentration for the radionuclides and the chemicals is uniformly distributed throughout the surface sediments of cells 52 and 64. Measurements taken at TRA during 1989 show that particulate matter concentrations in air averaged 15 $\mu g/m^3$, with an uncertainty at 2 standard deviations of 8 $\mu g/m^3$.[5] This was for particles with a diameter less then or equal to 10 micrometers. Incorporating a conservative approach, we have added the uncertainty to the mean value to establish an airborne particulate matter concentration of 23 $\mu g/m^3$. For a Gaussian distribution, this value represents a 98% confidence level of not being exceeded. If the airborne dust is assumed to contain contaminants similar to the concentrations in the pond surface sediment, then the product of the weighted-average concentration and 23 $\mu g/m^3$ produces the steady-state airborne concentration noted in the righthand column. This value is assumed accessible for a receptor who is outside, but near, the boundary of the warm waste pond.

Table I-1. Warm waste pond 0-2 feet sediment concentrations sediment Radionuclide concentrations

Nuclide	Half-Life (years)	Weighted Average Concentration (pCi/g)	Weighted Average Concentration (mg/kg)	Mass Loading Airborne Concentration (pCi/m^3)
Cr-51	7.585E-02	9.65E+01	1.04E-09	2.22E-03
Co-60	5.271E+00	4.61E+03	4.08E-06	1.06E-01
Sr-90	2.860E+01	5.73E+02	4.13E-06	1.32E-02
Ag-108m	1.270E+02	6.37E+01	2.45E-06	1.47E-03
Cs-134	2.062E+00	4.48E+01	3.47E-08	1.03E-03
Cs-137**	3.017E+01	1.15E+04	1.32E-04	2.64E-01
Eu-152	1.333E+01	1.07E+02	6.04E-07	2.45E-03
Eu-154	8.800E+00	4.92E+01	1.87E-07	1.13E-03
Eu-155	4.960E+00	9.67E+00	2.08E-08	2.22E-04
Th-228	1.913E+00	2.72E+01	3.32E-08	6.25E-04
Th-230	7.538E+04	1.42E+01	6.89E-04	3.27E-04
Th-232	1.450E+10	1.30E+00	1.22E+01	2.98E-05
U-232	6.890E+01	2.30E+01	1.03E-06	5.30E-04
U-234	2.450E+05	5.86E+00	9.40E-04	1.35E-04
U-238	4.468E+09	1.61E+00	4.78E+00	3.69E-05
Pu-238	8.774E+01	1.02E+01	5.97E-07	2.35E-04
Pu-239	2.412E+04	1.91E+01	3.08E-04	4.40E-04
Am-241	4.322E+02	8.19E+00	2.39E-06	1.88E-04
Cm-244	1.810E+01	6.75E+00	8.34E-08	1.55E-04

** . The Cs-137 activity is determined by the 661.6 keV gamma-ray of Ba-137m (Half-life = 2.5513 minutes).

Table I-1. Warm waste pond 0-2 feet sediment concentration (cont'd)

Sediment chemical concentrations

Chemical	Weighted Average Concentration (ppm) or (mg/kg)	Mass Loading Airborne Concentration (mg/m^3)
Arsenic	5.25E+00	1.21E-07
Be	2.20E+00	5.06E-08
Bis()phth**	1.49E+00	3.42E-08
Cd	3.12E+00	7.17E-08
Cr	3.38E+02	7.77E-06
Cyanide	9.83E-01	2.26E-08
Hg	2.69E+00	6.19E-08
Pb	1.78E+01	4.09E-07
Ag	2.19E+00	5.04E-08
Sulfide	2.77E+01	6.36E-07
Zinc	1.43E+02	3.29E-06

** Bis()phth=Bis(2-ethylhexyl)phthalate

Table I-2. Warm waste pond maximum water sample concentrations for radionuclides

Nuclide	Half-Life (years)	Maximum Concentration (pCi/ml)
H-3	1.233E+01	1970
Cr-51	7.585E-02	2.26E+01
Mn-54	8.556E-01	1.63E-01
Co-58	1.942E-01	6.32E-01
Co-60	5.271E+00	4.26E+00
Zn-65	6.678E-01	2.25E-01
Sr-90	2.860E+01	1.56E+00
Zr-95	1.753E-01	3.73E-02
Nb-95	9.574E-02	3.46E-02
Sb-124	1.648E-01	1.75E-01
Sb-125	2.730E+00	4.30E-02
I-131	2.200E-02	1.22E-01
Cs-134	2.062E+00	5.23E-02
Cs-137**	3.017E+01	1.56E+00
Ba-140	3.490E-02	1.13E-01
La-140	4.594E-02	6.72E+00
Hf-181	1.161E-01	2.86E-01
Hg-203	1.276E-01	5.86E-02
U-232	6.890E+01	2.30E-04
U-234	2.450E+05	2.68E-03
U-238	4.468E+09	5.60E-04
Pu-239	2.412E+04	5.40E-04
Am-241	4.322E+02	1.28E-03

** The Cs-137 activity is determined by the 661.6 keV gamma-ray of Ba-137m (Half-life = 2.5513 minutes).

4. EXPOSURE ASSESSMENT

4.1 Exposure Scenarios and Parameters

The hypothetical exposure scenario selected for the interim-action evaluation of the TRA Warm Waste Pond is a current occupational scenario. The occupational scenario is defined as a hypothetical worker (receptor) who can be potentially exposed to soil contaminants through inhalation and external exposure. This selection was based on the actual institutional control at the INEL. This scenario represents a reasonable maximum exposure, based on the actual conditions and restricted access to the operable unit.

The exposure assessment examined the potential exposure to contaminants present at the operable unit, based on available sampling data. Two exposure pathways were examined: inhalation of soil-contaminated air and direct exposure. These pathways were considered to be the most reasonable potential exposures for an occupational scenario, based on the actual conditions of TRA-WWP. The potential exposed individual was assumed to be located at the boundary of the operable unit.

The methods used in estimating exposure followed EPA risk assessment guidance[6]. Values for exposure parameters used in the calculation of intakes were derived from EPA Region 10 guidance[7] or were selected based on reasonable exposure criteria. Different occupational exposure conditions were examined for different inhalation rates and lengths of exposure, including upper-bound cases, average cases, and other selected time periods. The different exposure cases and corresponding exposure parameters are shown in Table I-3. The purpose of considering variations in exposure conditions was to be able to compare the effect of exposure parameters on the intake of the individual. Also, this will enable us to have an idea of the range of risks from the worst-case scenarios (i.e., 40 hrs/wk, 40 years exposure) to more realistic conditions (i.e., 5 hrs/wk, 1 yr exposure).

Table I-3. Exposure parameters for occupational scenarios used in the TRA-WWP Risk Assessment

Scenario	Inhalation Rate (m^3/d)	Body Weight (kg)	%Exposure	Exposure Frequency (d/yr)	Exposure Duration (yr)	Averaging Time (d)
EPA-Region 10, upper-bound	79	70	40	365	40	27375
EPA-Region 10, average	43	70	25	365	10	27375
Adjusted, upper-bound[a]	20	70	40	365	40	27375
Adjusted, average[a]	20	70	25	365	10	27375
40 hrs/wk, 50 wk/yr, 40 yrs	20	70	100	83.3	40	27375
5 hrs/wk, 50 wk/yr, 40 yrs	20	70	100	10.4	40	27375
40 hrs/wk, 50 wk/yr, 10 yrs	20	70	100	83.3	10	27375
5 hrs/wk, 50 wk/yr, 10 yrs	20	70	100	10.4	10	27375
40 hrs/wk, 50 wk/yr, 1 yr	20	70	100	83.3	1	27375
5 hrs/wk, 50 wk/yr, 1 yr	20	70	100	10.4	1	27375

a. Adjusted scenario based on inhalation rate of 20 m^3/d instead of EPA Region-10 values. 20 m^3/d is the average individual inhalation rate recommended by EPA.

4.2 Calculation of Contaminant Intake

Contaminant-specific intakes were calculated in the exposure assessment of chemicals. These intakes were then compared to toxicity values to determine risks associated with exposure to the evaluated chemicals.

The methodology for calculating chemical intakes followed EPA risk assessment guidance (see Reference 6). The calculation of intakes is used to evaluate the magnitude of exposure to potential contaminants. The equation used in the determination of inhalation intake is shown below:

$$I = \frac{C \times IR \times \%E \times EF \times ED}{BW \times AT} \qquad (1)$$

where

- I = intake of the contaminant (mg/kg/d)
- C = concentration of the contaminant in air (mg/m^3)
- IR = inhalation rate (m^3/d)
- %E = % exposure
- EF = exposure frequency (d/yr)
- ED = exposure duration (yr)
- BW = body weight (kg)
- AT = averaging time (d)

The air concentration values (mg/m^3) used in the calculation of intakes were obtained from available sampling data, as explained in the previous section (see Table I-1). The averaging time used in the above calculation is based on the lifetime of an individual (75 years) (see Reference 7).

The methodology used in the evaluation of radionuclides involves the comparison between the concentration in the media and the pathway-specific unit risk of the radionuclide. The estimation of intakes is not required in this procedure, because the unit risk value already accounts for exposure conditions. The derivation of unit risk factors will be discussed in the following section. Air concentration values used in the evaluation of

inhalation exposure were obtained from available sampling data (see Table I-1). Soil concentration values for the evaluation of external exposure were estimated from available sampling data, as explained below.

For external exposure of radionuclides, the exposure assessment was based on the actual institutional control at the TRA-WWP. As stated previously, access to the site is restricted. In addition to a fence, there are radiation barriers currently surrounding the TRA-WWP. The radiation barriers represent a radiation dose of 5 mrem/hr, based on radiation area control limits of 5 mR/hr. The radiation dose limit of 5 mrem/hr was used for the calculation of radiation dose and risk in the evaluation of external exposure of radionuclides.

5. TOXICITY ASSESSMENT

A toxicity assessment was conducted to identify the potential noncarcinogenic and carcinogenic effects of contaminants present at the TRA-WWP. Two primary sources were used in the determination of toxicity values: Integrated Risk Information System (IRIS)[8] and Health Effects Assessment Summary Tables (HEAST)[9].

5.1 Chemicals

The list of identified contaminants was examined and reference doses (RfDs) were determined for the evaluation of noncarcinogenic effects. The contaminants evaluated for noncarcinogenic effects were: arsenic, beryllium, bis(2-ethylhexyl)phthalate, cadmium, chromium-III, cyanide, mercury, lead, silver, and zinc. Established inhalation reference doses were available for only one contaminant (mercury). Toxicity values were then estimated for the remaining contaminants using available toxicity information from the Agency for Toxic Substances and Disease Registry (ASTDR) toxicological profiles[10-17] or threshold limit values from the American Conference of Governmental Industrial Hygienists (ACGIH)[18]. Sulfide was not examined because of a lack of toxicity data. Values used in the derivation of inhalation reference doses are shown in Appendix I-A. Table I-4 lists the inhalation reference doses used in the risk evaluation of noncarcinogenic effects. Table I-5 summarizes the major noncarcinogenic health effects for the evaluated contaminants.

Carcinogenic toxicity values were used in the evaluation of carcinogenic effects. Slope factors (SFs) were obtained from IRIS or HEAST. Four chemicals were evaluated for carcinogenic effects: arsenic, beryllium, bis(2-ethylhexyl)phthalate, and cadmium. This selection was based on available evidence of carcinogenic properties and carcinogenic toxicity values.

Arsenic is classified by EPA as a Group A carcinogen (human carcinogen). Cadmium is classified as Group B1 carcinogen (probable human carcinogen; limited evidence in humans). Beryllium and bis(2-ethylhexyl)phthalate are Group B2 carcinogens (probable human carcinogen; sufficient evidence in

Table I-4. Chronic inhalation reference doses (RfDs) used in the evaluation of noncarcinogenic effects of chemicals

Chemical	Inhalation Reference Dose (RfD) (mg/kg/d)
Arsenic	1.0E-05
Beryllium	6.0E-06
Bis(2-ethylhexyl)phthalate	6.0E-03
Cadmium	2.0E-05
Chromium-III	6.0E-04
Cyanide	6.0E-03
Mercury	9.0E-05
Lead	9.0E-06
Silver	1.0E-04
Zinc	6.0E-04

Table I-5. Summary of inhalation health effects of evaluated noncarcinogens

Chemical	Noncarcinogenic Inhalation Health Effects (see References 10-17, 19)
Arsenic	Irritation of the skin and mucous membranes, (dermatitis, conjunctivitis, pharyngitis, rhinitis)
Beryllium	Lung toxicity, pneumonitis and beryllosis
Bis(2-ethylhexyl) phthalate	Hepatotoxicity, reproductive toxicity (animal studies)
Cadmium	Irritation of the lung, emphysema (long-term exposure), kidney injury
Chromium-III	Irritation of the skin and respiratory tract, developmental and reproductive toxicity (animal studies)
Cyanide	CNS toxicity, cardiac and respiratory effects
Mercury	Kidney and CNS (low-levels); respiratory, cardiovascular an gastrointestinal (high-levels)
Lead	Hematological effects, developmental toxicity
Silver	Respiratory irritation, gastrointestinal effects, skin irritation (dust)
Zinc	Respiratory effects (impairment of pulmonary function, irritation)

Table I-6. Inhalation slope factors (SFs) used in the evaluation of carcinogenic effects of chemicals

Chemical	Inhalation Slope Factor (SF) $(mg/kg/d)^{-1}$	EPA Classification[a]
Arsenic	5.0E+01	A
Beryllium	8.4E+00	B2
Bis(2-ethylhexyl)phthalate	1.4E-02[b]	B2
Cadmium	6.1E+00	B1

a. EPA Classification: A = human carcinogen (sufficient evidence in humans)
B1 = probable human carcinogen (limited evidence in humans)
B2 = probable human carcinogen (sufficient evidence in animals with inadequate or lack of evidence in humans)

b. Slope factor for bis(2-ethylhexyl)phthalate is for ingestion (oral).

animals). The oral slope factor was used in the evaluation of bis(2-ethylhexyl)phthalate because there was no available inhalation toxicity value for the chemical. Inhalation slope factors are shown in Table I-6.

5.2 Radionuclides

Radionuclides are classified as Group A human carcinogens. Nineteen radionuclides were identified as contaminants present at the TRA-WWP. Sixteen radionuclides were evaluated for carcinogenic effects for both inhalation and external exposure. This selection included the contaminants present at the highest concentrations and those with available toxicity values. The SFs values (inhalation and external exposure) for the selected radionuclides are shown in Table I-7. Table I-8 shows a summary of carcinogenic effects for the evaluated carcinogens (chemicals and radionuclides).

The slope factors of radionuclides were used to calculate pathway-specific unit risk values. Unit risk (UR) values were used in the evaluation of carcinogenic risks of radionuclides. These values were derived using specific exposure parameters for the different exposure scenarios. The following equation was used to derive the inhalation unit risk (see Reference 9):

$$UR = SF \times IR \times \%E \times EF \times ED \qquad (2)$$

where

UR = unit risk for inhalation $(pCi/m^3)^{-1}$
SF = slope factor for inhalation (risk per pCi inhaled)
IR = inhalation rate (m^3/d)
%E = % exposure
EF = exposure frequency (d/yr)
ED = exposure duration (yr)

For the derivation of external exposure unit risk, the following equation was used (see Reference 9):

$$UR = SF \times Soil\ Depth \times Soil\ Density \times ED \times \%E \qquad (3)$$

Table I-7. Inhalation and external exposure slope factors (SFs) used in the evaluation of carcinogenic effects of radionuclides

Radionuclide	Inhalation SF $(pCi)^{-1}$	External Exposure SF $(yr/(pCi/m^2))$
Cr-51	3.0E-13	1.9E-12
Co-60	1.6E-10	1.3E-10
Sr-90	5.6E-11	0.0E+00
Cs-134	2.8E-11	8.9E-11
Cs-137	1.9E-11	3.4E-11[a]
Eu-152	1.2E-8	6.3E-11
Eu-154	1.4E-10	6.8E-11
Th-228	7.7E-08	1.6E-13
Th-230	3.1E-08	5.9E-14
Th-232	3.1E-08	4.6E-14
U-234	2.7E-08	5.7E-14
U-238	2.4E-08	4.6E-14
Pu-238	4.2E-08	6.1E-14
Pu-239	4.1E-08	2.6E-14
Am-241	4.0E-08	1.6E-12
Cm-244	2.7E-08	5.8E-14

a. The external exposure slope factor for Cs-137 is based on Ba-137m. The external exposure risk from Cs-137 is due to the photon radiation emitted by Ba-137m, its immediate short-lived decay product (half-live = 2.55 minutes).

Table I-8. Summary of carcinogenic effects of evaluated carcinogens

Chemical	Target Organ/Type of Cancer[9] Inhalation
Arsenic	Respiratory tract
Beryllium	Lung
Bis(2-ethylhexyl)phthalate	Not available for inhalation; Liver (oral)
Cadmium	Respiratory tract
Radionuclides	**Target Organ/Type of Cancer[20] Inhalation/External Exposure**
All radionuclides	Radiation-induced cancers in whole-body organs/tissues (i.e. gonads, breast, lung, red marrow, thyroid, bone marrow, etc.)

where

UR	=	unit risk for external exposure $(pCi/g)^{-1}$
SF	=	slope factor for external exposure (risk per year per pCi/m^2)
Soil Depth	=	0.1 m
Soil Density	=	1.8 E+6 g/m^3 (specific for TRA, see Reference 1)
%E	=	% exposure
ED	=	exposure duration (yr)

In the evaluation of external exposure, radiation doses (mrem/hr) were calculated for each radionuclide using the available soil sampling data from TRA-WWP (see Table I-1). The following equation was used:

$$D = C \times (1\mu Ci/1E+6\ pCi) \times Soil\ depth \times Soil\ Density \times DCF \quad (4)$$

where

D	=	radiation dose (mrem/yr)
C	=	Concentration of contaminant in the soil (pCi/g)
Soil depth	=	0.1 m
Soil density	=	1.8 E+6 g/m^3 (specific for TRA)
DCF	=	dose conversion factor for external exposure (effective dose, $(mrem/yr)/(\mu Ci/m^2)$)

The dose was then converted to mrem/hr for each of the exposure scenarios.

Based on the calculated total external radiation dose from the pond sediments (for an individual standing on the contaminated source), the major contributors were Co-60, Cs-137 (Ba-137m), Eu-152, Cs-134, and Eu-154. The ratio of radionuclide dose to total dose was then used to estimate the contribution of each radionuclide to the radiation dose of 5 mrem/hr (based on a radiation field of 5 mR/hr) at the enclosed radiation area around the pond, which represents the location of the potential receptor. A back-calculation approach was used to estimate the external-exposure cancer risk from the radiation field at the TRA-WWP boundary. Soil concentrations for each

radionuclide, corresponding to a total radiation dose of 5 mrem/hr, were estimated and then used in the cancer risk evaluation for external exposure. Estimated soil concentrations for the evaluated radionuclides and their corresponding dose conversion factors (DCFs)[20] are shown in Table I-9.

Table I-9. Dose conversion factors and estimated soil concentrations of radionuclides evaluated for external exposure

Radionuclide	External Exposure DCF (mrem/yr)/μCi/m^2)	Estimated Soil Concentration (pCi/G)
Co-60	2.27E+02	6.32E+02
Cs-134	1.58E+02	6.15E+00
Cs-137	6.11E+01[a]	1.58E+03
Eu-152	1.11E+02	1.47E+01
Eu-154	1.21E+02	6.75E+00

a. The external exposure DCF for Cs-137 is based on Ba-137m. The external exposure risk from Cs-137 is due to the photon radiation emitted by Ba-137m, its immediate short-lived decay product (half-live = 2.55 minutes).

6. RISK CHARACTERIZATION

The risk characterization involved the evaluation of potential noncarcinogenic and carcinogenic effects at the TRA-WWP. The outputs from the exposure assessment and toxicity assessment were combined to determine the risk associated with contaminants at the TRA-WWP.

The potential for noncarcinogenic toxicity was evaluated by comparing the exposure level (intake) of the contaminant with the inhalation reference dose. This ratio is defined as a hazard quotient, as shown below:

$$HQ = \frac{I}{RfD} \qquad (5)$$

where

HQ = hazard quotient, unitless
I = intake of the contaminant (mg/kg/d)
RfD = reference dose (mg/kg/d)

If the HQ exceeds 1, there may be concern for potential noncancer effects, because the intake is exceeding the reference dose. If the HQ is less than 1, the contaminant concentration is below the threshold of potential noncarcinogenic effects and no adverse effects are expected from exposure to the contaminant.

To assess the overall potential for noncarcinogenic effects, a hazard index was calculated. The hazard index is equal to the sum of the hazard quotients, as follows:

$$HI = \sum \frac{I_i}{RfD_i} \qquad (6)$$

where

HI = hazard index, unitless

I_i = intake for the *ith* contaminant (mg/kg/d)

RfD_i = RfD for the *ith* contaminant (mg/kg/d)

When the HI exceeds 1, there may be concern for potential adverse health effects (other than cancer) based on the aggregate risks from multiple substances.

The potential for carcinogenic effects at the TRA-WWP was evaluated by calculating the cancer risk for both chemicals and radionuclides. For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime, as a result of exposure to the potential carcinogen. The following equation was used to estimate cancer risk from chemicals:

$$R \stackrel{*}{=} I \times SF \qquad (7)$$

where

R = cancer risk, expressed as a unitless probability

I = intake of the contaminant (mg/kg/d)

SF = slope factor $(mg/kg/d)^{-1}$

For radionuclides, cancer risks were calculated by comparing the concentration of the radionuclide in the medium of concern (air or soil) to the appropriate unit risk value, as follows:

$$R = C \times UR \qquad (8)$$

where

R = cancer risk, expressed as a unitless probability

C = concentration of the radionuclide in air (pCi/m^3) or soil (pCi/g)

UR = pathway-specific unit risk for: inhalation $(pCi/m^3)^{-1}$ or external exposure $(pCi/g)^{-1}$

The approach used in the above equations assumes a linear dose-response relationship, where the slope factor or unit risk is a constant and the risk is directly related to the intake or concentration of the contaminant. The above linear equation was used when intakes and risk levels were low. When intakes were high (i.e., risk above 0.01), the following relationships were used instead:

For chemicals:

$$R = 1 - exp\ (-I \times SF) \qquad (9)$$

For radionuclides:

$$R = 1 - exp\ (-C \times UR) \qquad (10)$$

where

- R = cancer risk, expressed as a unitless probability
- I = intake of the chemical (mg/kg/d)
- SF = slope factor $(mg/kg/d)^{-1}$
- C = concentration of the radionuclide in air (pCi/m^3) or soil (pCi/g)
- UR = pathway-specific unit risk of the radionuclide for inhalation $(pCi/m^3)^{-1}$ or external exposure $(pCi/g)^{-1}$

To assess the overall potential for carcinogenic effects from exposure to multiple carcinogens (chemicals or radionuclides), the following equation is used:

$$R_t = \sum (R)_i \qquad (11)$$

where

- R_t = total cancer risk, unitless probability
- R_i = risk for the *ith* contaminant (chemical or radionuclide)

The above equation represents an approximation of the precise equation for combining risks, which accounts for the joint probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens. The simple additive equation was used when cancer risks were low (less than 0.1). For high-risk contaminants (i.e., two contaminants R1 and R2) the following equation was used instead:

$$R_t = R_1 + R_2 - (R_1 \times R_2) \qquad (12)$$

where

R_t = total cancer risk, unitless probability

R_1, R_2 = risk of contaminant 1 and 2

Carcinogenic risks were also calculated for multiple pathways, in the case of radionuclides. Risk values for inhalation and external exposure were added to obtain total cancer risk for both exposure pathways.

7. RESULTS OF HUMAN HEALTH RISK ASSESSMENT

The individual calculations and results of the risk characterization are shown in Appendix B. As explained earlier, different exposure conditions were evaluated, so as to examine the worst-case, as well as more realistic, scenarios (see Table I-3).

The evaluation of noncarcinogenic effects showed that all HQs were less than one for individual chemicals . The HI was also less than one, which indicates that no adverse health effects (noncarcinogenic effects) are expected from the evaluated contaminants. A graphic presentation of noncarcinogenic results (for all exposure conditions) is shown in Figure I-2.

Carcinogenic risks for the inhalation pathway were found to be in the range of 2.9 E-10 to 6.4 E-7 for chemicals and 3.2 E-8 to 7.2 E-5 for radionuclides. The high end of the range represents the upper-bound exposure conditions based on EPA Region 10 exposure parameters. The NCP target risk range is between 10-6 and 10-4, which means that the target risk range was not exceeded for the inhalation of chemicals or radionuclides. Figure I-3 and Figure I-4 show the carcinogenic risk results for the inhalation pathway for chemicals and radionuclides, respectively.

Carcinogenic risks for the external exposure pathway for radionuclides were found to be above the recommended target risk range, with values between 7.4 E-4 and 3.3 E-1. External exposure results are shown in Figure I-5.

Total cancer risk was also calculated for both exposure pathways (for radionuclides) and was in the range of 7.4 E-4 to 3.3 E-1 (see Figure I-6).

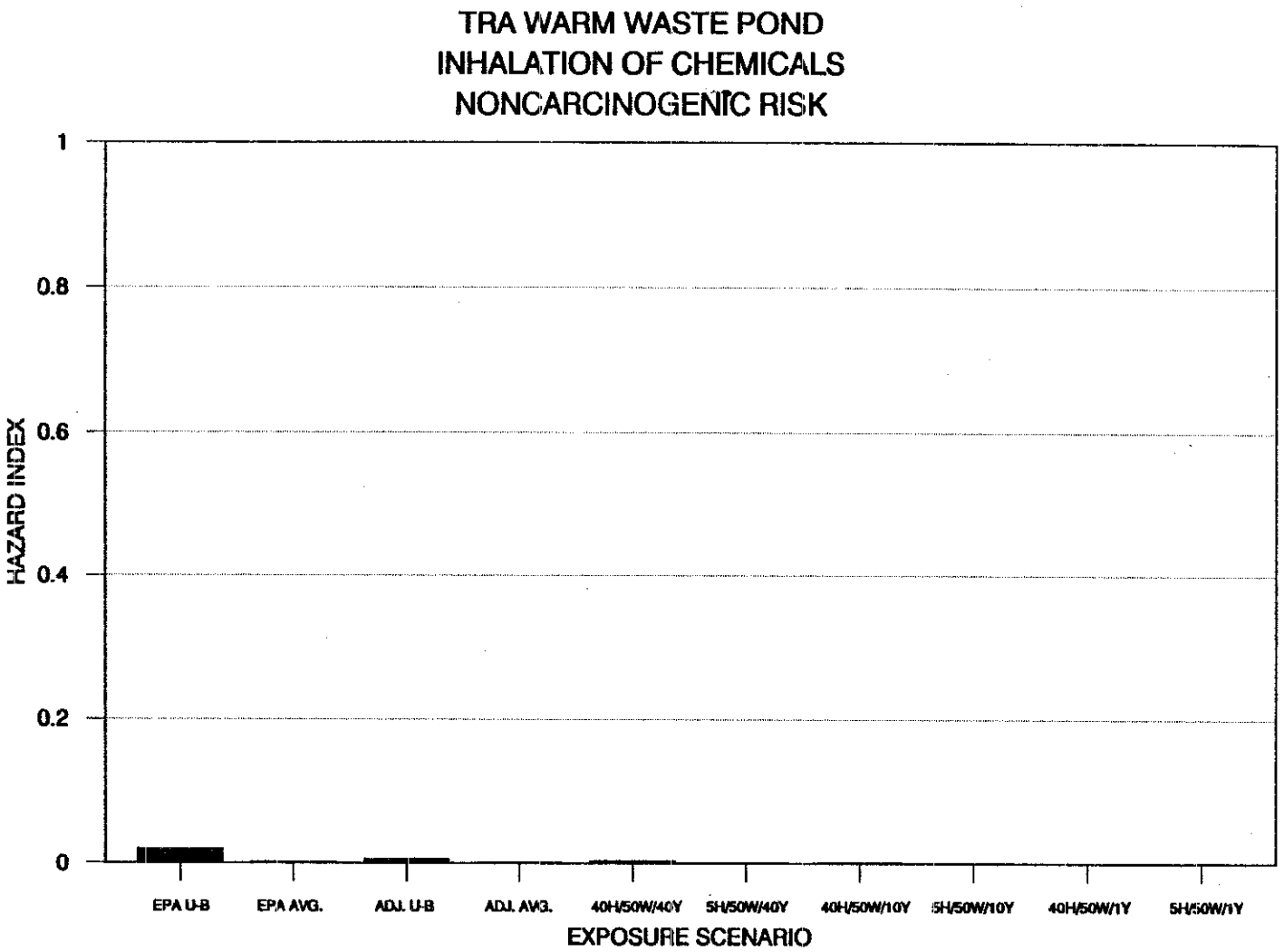

Figure I-2. Hazard index results for noncarcinogenic effects of chemicals at the TRA Warm Waste Pond. (see Table I-3 for exposure scenarios)

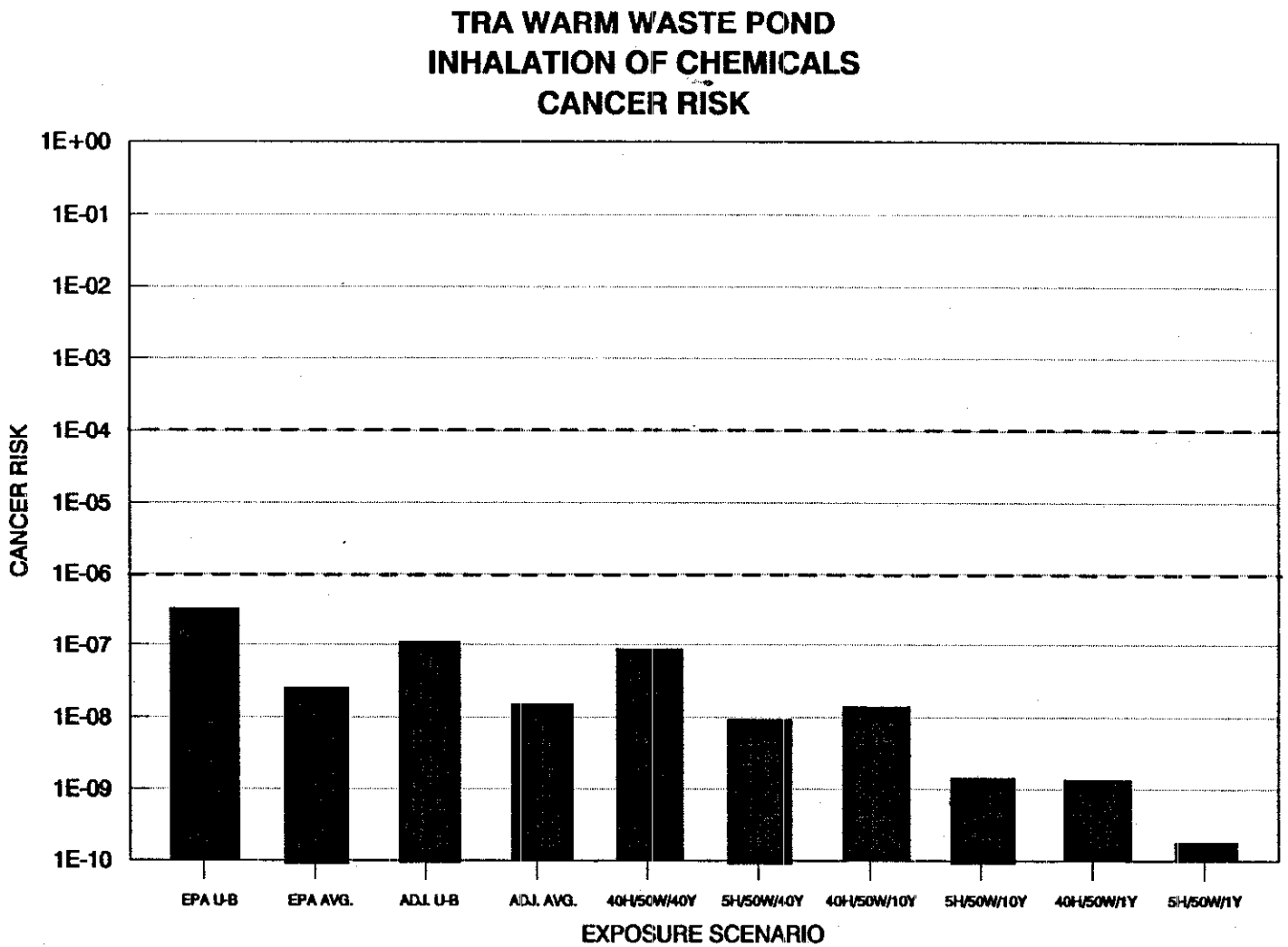

Figure I-3. Cancer risk results for inhalation of chemicals at the TRA Warm Waste Pond. (see Table I-3 for exposure scenarios)

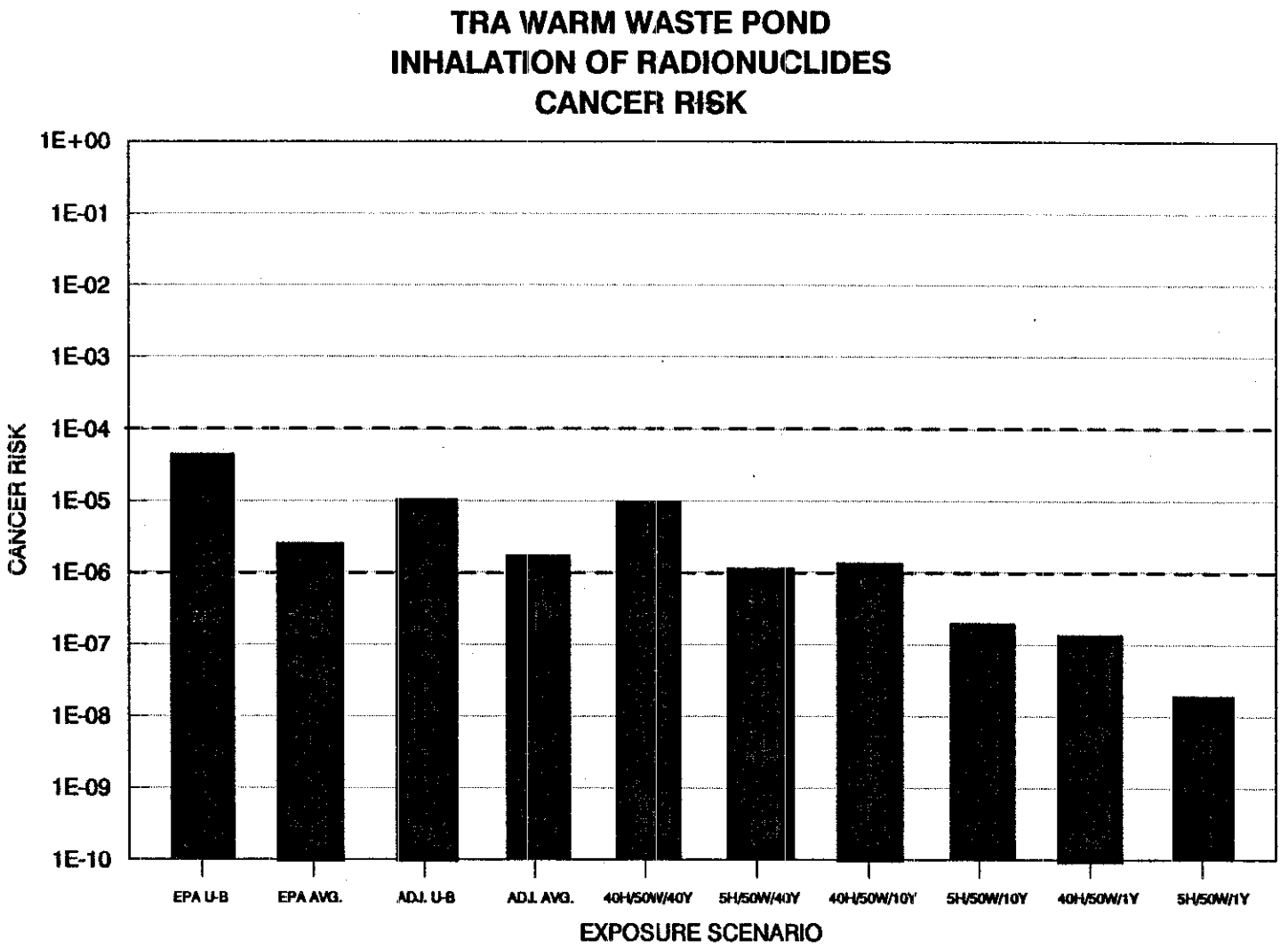

Figure I-4. Cancer risk results for inhalation of radionuclides at the TRA Warm Waste Pond. (see Table I-3 for exposure scenarios)

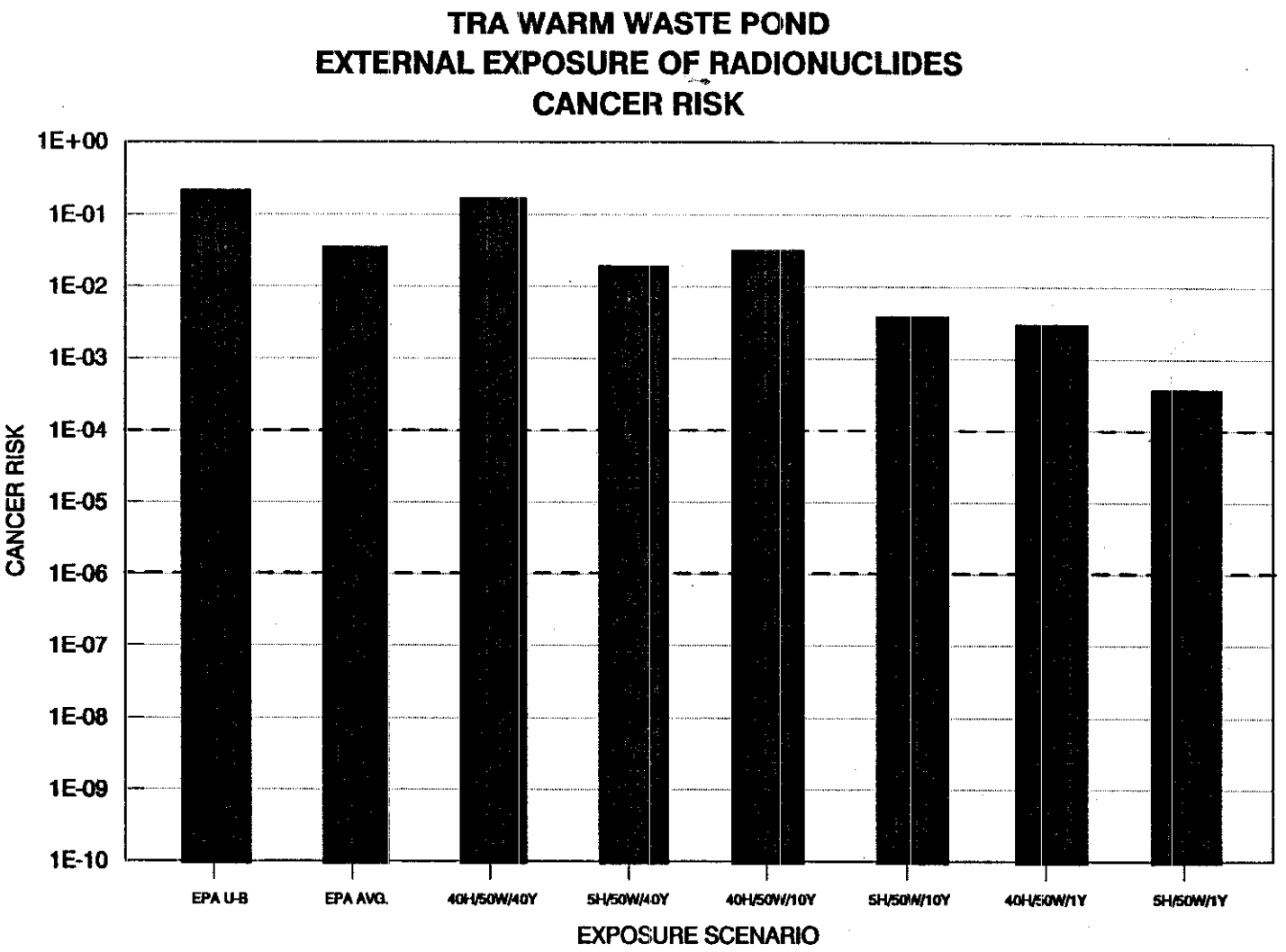

Figure I-5. Cancer risk results for external exposure to radionuclides at the TRA Warm Waste Pond. (see Table I-3 for exposure scenarios)

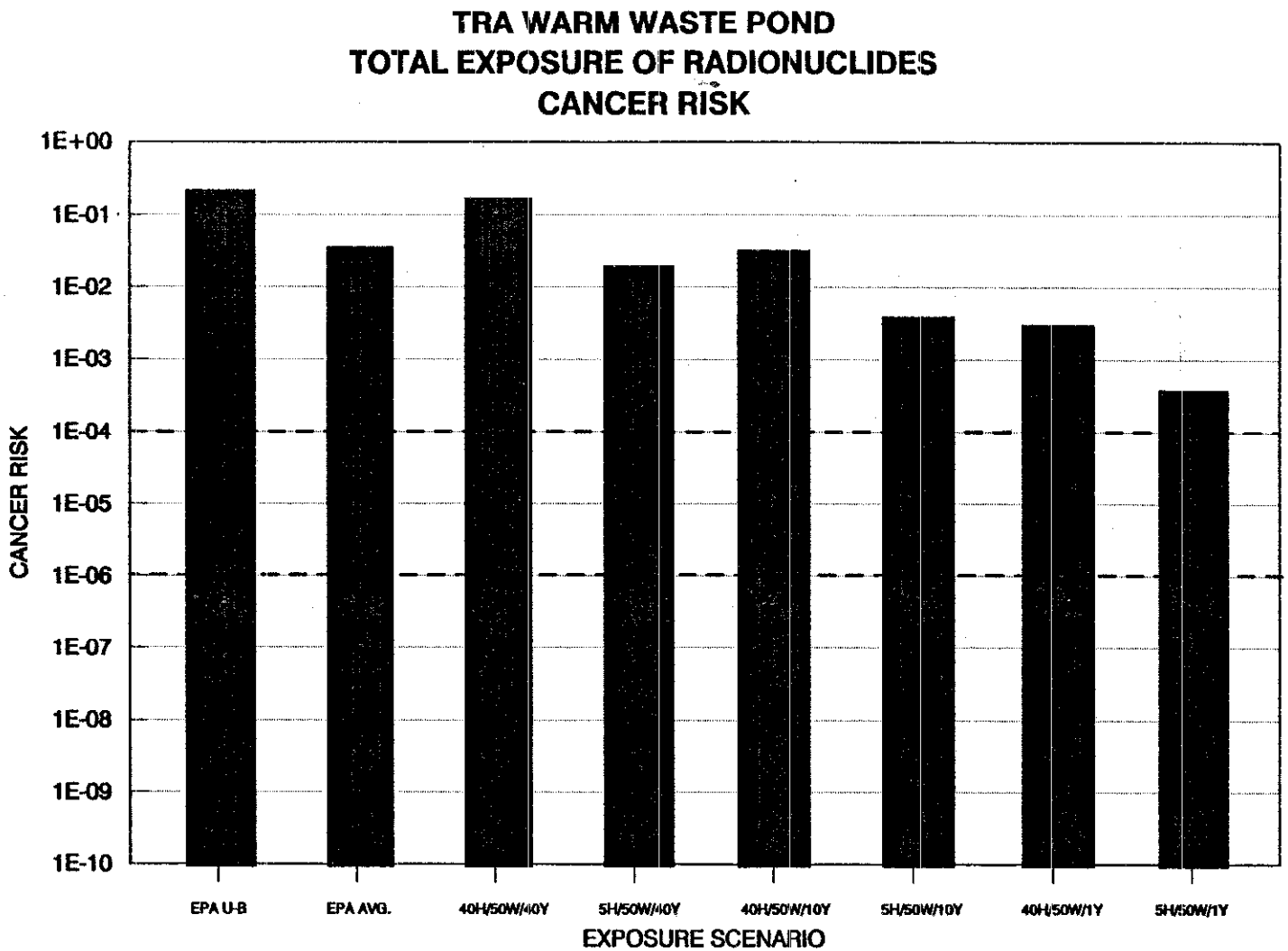

Figure I-6. Cancer risk results for total exposure to radionuclides at the TRAWarm Waste Pond (inhalation and external exposure).
(see Table I-3 for exposure scenarios)

8. DISCUSSION OF UNCERTAINTIES

The performed risk evaluation described the potential risk associated with identified contaminants at the TRA-WWP. Although the presented results are accurate for the evaluated concentrations of contaminants at TRA-WWP, it is also important to realize that the risk values carry some uncertainties inherent in the risk assessment process. The calculated values for hazard index and cancer risk represent estimates of potential effects and do not represent characterization of absolute risks at the TRA-WWP. The risk measures are conditional estimates, dependent on a considerable number of assumptions about exposure and toxicity.

Several factors that should be taken into consideration when evaluating the risk results are the uncertainties involved in identifying and quantifying: contaminants, exposure assessment assumptions, toxicity values, and risk calculation methods.

There are some uncertainties associated with identifying contaminants at the TRA-WWP. The evaluation of site contaminants was based on 1988 sampling data and does not represent the actual condition of the TRA-WWP. In regard to estimating air concentrations, conservative assumptions were included in the mass-loading approach, which can overestimate the exposure to the receptor. The resulting air concentrations represent an upper-bound (98% confidence level) estimate of potential air exposure, assuming that the airborne dust contains contaminants similar to the concentrations in the pond surface sediment.

Uncertainties related to the exposure assessment include the selection of exposure conditions and exposure factors that describe the receptor scenario at TRA-WWP. As observed in the results, estimates of intake are dependent on the selection of exposure parameters (see Table I-3), which will determine the extent of risk to the receptor. Due to the uncertainties involved in the selection of exposure factors, this evaluation included several exposure conditions, from the EPA Region 10 upper-bound case to a more realistic one-year exposure. The Region 10 upper-bound scenario represents

the reasonable maximum exposure suggested by EPA Region 10. We do not anticipate that potential exposures and risks will exceed the resulting values for the upper-bound case. In all cases, the risks are dependent on the likelihood of access to the contaminated area and the period of exposure. Another exposure assessment uncertainty is the assumption that the exposure concentrations will remain constant throughout the period of exposure. This assumption will cause an overestimation of risks because depletion of source contaminants is not considered. The steady-state source assumption represents a conservative estimation of exposure. Also, contributions from radioactive decay products were not considered in the exposure assessment of radionuclides.

There are also some uncertainties related to the toxicity assessment and risk characterization. Uncertainties related to the toxicity values used in the characterization of noncarcinogenic and carcinogenic risks can include: high-dose to low-dose extrapolation of adverse effects, extrapolation from animal studies, short-term to long-term exposure, and differences in population sensitivities. It is important to realize that toxicity values (reference doses or slope factors) are estimates with uncertainties spanning perhaps an order of magnitude or greater. One of the defined uncertainties in the TRA-WWP evaluation was the lack of established reference doses for some contaminants and the use of estimated values in the determination of noncarcinogenic effects. Conservative assumptions were made in the toxicity evaluation and uncertainty factors were included in the estimated reference dose, such as to account for differences in human sensitivities (UF = 10) and uncertainties related to NOAEL (No Adverse Effect Level) or LOAEL (Low Adverse Effect Level) values (MF = 10). The use of conservative assumptions can generate overestimates of risks, but due to the uncertainties involved in this process, it was considered necessary to include these factors in the estimation of reference doses.

For the evaluation of carcinogenic effects, all toxicity values used in the risk characterization have been verified by EPA. Evidence of carcinogenicity for the evaluated carcinogens was high (EPA classification: A, B1, or B2). Some uncertainty was identified in the use of an ingestion slope factor in the evaluation of bis-(2-ethylhexyl)phthalate. Nevertheless,

the contaminant was included in the risk assessment as a conservative measure, based on its classification as a probable carcinogen. In respect to the radionuclides evaluation, there is a high confidence in the available toxicity data regarding their carcinogenic properties, because cancer risk values for radionuclides are based on human epidemiological data. Still, there is always some uncertainty related to calculated values because of extrapolation to low doses from high-dose data.

Other concerns in the risk characterization are uncertainties associated with summing risks or hazard indices. The assumption of dose additivity ignores possible synergism or antagonism among substances. In spite of that assumption, EPA suggests we should assume that risks are additive, recognizing that the necessary data to assess these interactions are rarely available and this approach will prevent the underestimation of risks at the site.

9. CONCLUSIONS

The risk results indicate that the chemicals do not pose a human health threat in terms of noncarcinogenic effects based on the evaluated exposure pathway (inhalation). Carcinogenic effects (for inhalation) for the evaluated chemical carcinogens were also below the level of concern, based on the NCP target risk range of 10-4 to 10-6.

The risk results from the inhalation of radionuclides indicate that risks are within the NCP target range of acceptable cancer risks. When the upper-bound case is considered, the risk approaches 10-4. As stated before, there are some uncertainties associated with the estimation of risks, and the upper-bound case represents a very conservative scenario that might not be realistic based on the limited access to the TRA-WWP.

The risk results from the evaluation of external exposure to radionuclides indicate that there is a carcinogenic health concern from contaminants present at TRA-WWP. The cancer risks for external exposure exceeded the acceptable NCP range for all exposure conditions. The external exposure calculation was based on the actual radiation dose limit of 5 mrem/hr (based on 5mR/hr) for a controlled radiation area. It is important to recognize that this radiation limit exceeds the EPA or NCP target range, based on risk assessment calculations. Although there are some uncertainties associated with risk estimation procedures, the results demonstrate a potential cancer risk problem as a result of external exposure to radionuclides.

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